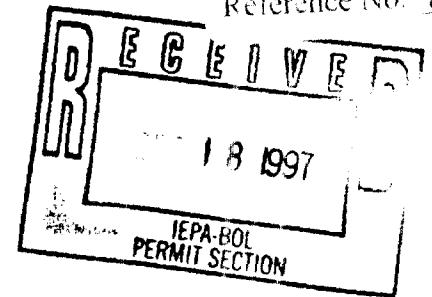


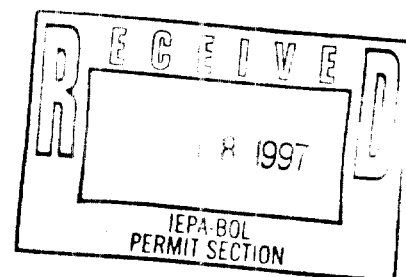
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ROUX Associates, Inc.

ENVIRONMENTAL CONSULTING & MANAGEMENT



SUMMARY OF GROUND-WATER QUALITY CONDITIONS

**W.G. Krummrich Plant
Solutia, Inc., Sauget, Illinois**

Volume I of II

December 9, 1997

Prepared for:

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FIGURE

1. Proposed Monitoring Wells

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1.0 INTRODUCTION

In September 1977, Roux Associates, Inc. (Roux Associates) was requested by Solutia, Inc. (Solutia) to compile existing hydrogeologic information and water quality data from previous reports and various ground-water sampling rounds. Most of the information was obtained from two reports that were previously submitted to the Illinois Environmental Protection Agency (IEPA) and are listed below.

- Plant-Wide Assessment of Ground-Water Conditions at the W.G. Krummrich Plant, Monsanto Company, Sauget, Illinois, vol. I, II and III, Geraghty & Miller, Inc., September 1986.
- Evaluation of Ground-Water Quality Conditions at W.G. Krummrich Plant, Monsanto Company, Sauget, Illinois, Geraghty & Miller, Inc., May 1993.

In November 1983, Geraghty & Miller initiated a hydrogeologic assessment of ground-water conditions at the W.G. Krummrich Plant with the installation of 12 shallow wells to obtain an initial understanding of ground-water quality (see Figure 2 from the 1986 report located in Appendix A of this report). Since that initial investigation, additional shallow and deeper wells have been installed at the Site and sampled for USEPA priority pollutant compounds plus additional site-specific compounds (1984 through 1991) and then for Appendix IX compounds (1992 and 1994). The first 12 wells located were in the production area; however, the expanded monitoring well network included other areas of the plant: Lot F (west of the production areas), Village of Sauget property (west of Lot F), and Lot H (Site R landfill). The production area/Lot F and Lot H are shown in Figures 1 and 2, respectively, from the 1993 report (see Appendix B). Lot H has not been included in the evaluation presented in this report because it is being investigated as part of another study, as agreed with the IEPA. The Village of Sauget property is also not included in this evaluation because monitoring wells on Village property were installed to specifically monitor potential sources of ground-water impacts that are located on Village property.

Geraghty & Miller proposed a semiannual ground-water monitoring program to Monsanto in the 1986 report based on its hydrogeologic investigation (Geraghty & Miller, Inc., 1986a). The monitoring program that was proposed in the 1986 Geraghty & Miller report is described in this report. The overall purpose of the monitoring program was to characterize plant-wide ground-water quality and to monitor changes in water quality over time.

Since September 1986, only a few additional wells have been installed at the plant. In September/October 1987, four wells were installed downgradient of the Route 3 drum site (southwest corner of Lot F) to monitor water quality in that area. Two shallow wells (Wells GM-58A and GM-59A) were installed downgradient of the Route 3 drum site at the western boundary of Lot F to monitor ground-water quality in the shallow zone. In addition, a shallow zone well (GM-54A) and an intermediate zone well (GM-54B) were installed further downgradient on Village of Sauget property to monitor ground-water quality in these zones at a greater distance from the Route 3 drum site. The geologic logs, well construction details, and water quality data for these four additional wells are provided in the appendices of this report.

In January 1993, Geraghty & Miller was requested by Monsanto Company to prepare an evaluation of the plant-wide ground-water quality data that have been collected since the semiannual monitoring program was initiated in 1986. These data were evaluated in the report prepared by Geraghty & Miller in 1993 and are incorporated into this document.

Some of the figures are not of good quality because they are reproductions of maps from the older reports. Maps of better quality may be available from either Solutia or IEPA provided that copies of those reports can be located.

2.0 HYDROGEOLOGY

The W.G. Krummrich Plant is situated on the flood plain of the Mississippi River, south of East St. Louis, at Sauget, Illinois. The flood plain is locally named the American Bottoms, and contains unconsolidated valley fill deposits composed of recent alluvium (Cahokia Alluvium), which overlies glacial material (Henry Formation). Published information indicates that these unconsolidated deposits are underlain by bedrock of Mississippian age, which consists of limestone and dolomite with lesser amounts of sandstone and shale.

The Cahokia Alluvium (recent deposits) consists of unconsolidated, poorly sorted, fine-grained materials with some local sand and clay lenses. The material is about 40 feet thick and becomes coarser with depth. These recent alluvium deposits unconformably overlie the Henry Formation, ^{WHICH} is about 95 feet thick at the Mississippi River and becomes thinner with increasing distance from the river. These valley-train materials are generally medium-to-coarse sand and gravel and also increase in grain size with depth. In some areas, till and/or boulder zones were encountered 10 to 15 feet above the bedrock.

During the various drilling programs conducted onsite, the alluvium was determined to consist of fine gray and brown silty sand up to 40 feet below land surface. A cross section of the study area is provided for the line of section shown in Figure 2, and presented in Figure 3 (Appendix A). The geologic data show that the unconsolidated deposits range from 140 feet thick near the river to about 110 feet in the eastern part of the Monsanto property. The geologic logs for the drilling programs conducted by Geraghty & Miller are provided in Appendix C.

During the drilling programs conducted by Geraghty & Miller across the entire site, the contact or boundary between the Cahokia Alluvium and the Henry Formation could not be distinguished; however, this is not necessary for evaluating the hydrogeology of the area. Aquifer properties such as transmissivity are more important than geological distinctions. To simplify the flow system, the unconsolidated deposits were divided into three zones according to relative transmissivities: a water-table (shallow) zone, intermediate zone, and a deep zone.

The water-table zone consists of the Cahokia Alluvium (recent deposits), which is an unconsolidated, fine-grained silty sand. This zone is considered to be 30 feet thick, starting at the water table and continuing down to the medium sand deposits of the Henry Formation.

The intermediate zone is much coarser than the overlying water-table zone. This zone contains medium-grained sand representing the upper portion of the Henry Formation, a Wisconsinian glacial outwash in the form of valley-train deposits. Valley-train deposits are long narrow bodies of outwash, deposited by meltwater streams far beyond the terminal moraine and confined within the walls of a valley. The Henry Formation is characterized by medium-to-coarse sand that becomes coarser with depth. The thickness of the zone is estimated to be about 40 feet.

Below the intermediate zone is the deep zone, which is marked by coarse deposits of the lower portion of the Henry Formation. In some areas, till and/or boulder zones were encountered 10 to 15 feet above the bedrock. The zone is estimated to be about 40 feet thick.

3.0 GROUND-WATER MOVEMENT

Historical ground-water movement, as well as more recent ground-water flow conditions (1984 and 1985) are discussed below.

3.1 Historical Ground-Water Flow Patterns

Ground water in the Henry Formation occurs under leaky artesian and water-table conditions. Recharge in this area occurs from 1) precipitation; 2) induced infiltration of surface water from the Mississippi River and small streams as a result of ground-water pumping; and 3) underflow from the east. Recharge by induced infiltration occurs where pumping large quantities of ground water has lowered the water table below the water level in the Mississippi River and nearby streams.

In the past, large supplies of ground water were withdrawn from permeable sand and gravel of the valley fill (Henry Formation) in the East St. Louis-Sauget-Cahokia area. The coarsest deposits (and most favorable for pumping large volumes of ground water) are located near bedrock. Most, if not all, of the wells are screened in these deposits (Ritchey, et al., 1984).

Ground-water pumpage in the Monsanto area was largely from industrial wells. Figure 4 (Appendix A) illustrates the estimated pumpage in the East St. Louis-Sauget-Cahokia area from 1890 to 1980. Pumpage increased up to 1962 as demands required greater withdrawals. As a result of increased ground-water conservation at one industry (1962-1965), the closing of two major ground-water using industries (1970-1971), and the conversion to the use of the Mississippi River as a source of water (1972-1977), ground-water withdrawals decreased from 35.5 million gallons per day (mgd) in 1962 to 0.5 mgd in 1980 (Ritchey, et. al, 1984). A regional deterioration in water quality was probably the primary reason for changing from ground water to surface water.

The changes in ground-water withdrawals from 1961 to 1980, and the resultant effect on the potentiometric surface in the Henry Formation, are illustrated in Figures 5 to 7 (Appendix A). Figure 5 (based on 1961 data) clearly depicts locations of pumping centers and their associated cones of depression. Monsanto's supply wells (in the plant area) appear to be at the center of the

largest cone of depression, and they drew ground water from all directions. Therefore, ground-water flow was toward the Monsanto property from adjacent properties, which include AMAX, Cerro and Mid-West Rubber. A smaller and deeper cone of depression, due to the pumping of Monsanto's Ranney Well No. 3, is evident about one mile west of the main pumping center, adjacent to the Mississippi River.

Ground-water levels in June 1973 (Figure 6, Appendix A) were at record high elevations, due primarily to a prolonged period of high river stage and extensive flooding in 1973. It is also important to note that ground water beneath the W.G. Krummrich Landfill was being drawn away from the Mississippi River toward the plant process area production wells. In addition, ground water on adjacent properties was still traveling toward the Monsanto wells.

In November 1980 (Figure 7, Appendix A), ground-water flow was toward the Mississippi River for the first time since the pre-pumping period. The re-establishment of natural flow conditions in the early 1980s represents a major ground-water flow reversal which resulted from the cessation of large ground-water withdrawals.

3.2 Recent Ground-Water Flow Patterns

In order to assess ground-water flow patterns in 1986, Geraghty & Miller, Inc. inventoried existing wells within an approximate 2-mile radius from the Monsanto property. These wells are shown in Figure 1 (Appendix A) and available well construction details are provided in Table 1 (Appendix D). Any supply well that could potentially influence ground-water flow patterns on the site was mapped. Well information was obtained from files of the Illinois Geological Survey, the Illinois State Water Survey and the U.S. Geological Survey. Figure 4 (Appendix A) shows the dramatic decrease in ground-water use from 1962 to 1980 for the East St. Louis-Sauget-Cahokia area. At the present time, ground water is not used for potable supplies. The small ground-water withdrawals are limited to industrial use.

The 1984 ground-water flow patterns have been illustrated for the three hydrogeologic zones. The configuration of the water table and the potentiometric surface for the intermediate and deep zones have been drawn for August 1984 and November 1985 to illustrate what effect rising and falling levels in the Mississippi River have on ground-water flow patterns during periods of high and low river stage.

Water-level measurements were made in all available wells between August 24 and 27, 1984 and again on November 21 and 22, 1985 (Tables 2 and 3 in Appendix D). The construction details for these wells are provided in Tables 4, 5, and 6 (Appendix D). Figures 8 through 10 depict water-level elevations in August 1984 and Figures 11 through 14 illustrate the configuration of the water-table and potentiometric surfaces in November 1985 (Appendix A).

3.2.1 August 1984

The configuration of the water table in August 1984 (Figure 8, Appendix A) demonstrates that ground-water flow in the uppermost saturated unit (water-table zone) is toward the Mississippi River. At that time, the Mississippi River stage was 5 to 7 feet above the U.S. Corps of Engineers datum at the Market Street station in St. Louis.

A ground-water mound exists beneath a portion of the plant area. The mound appears to be caused by a combination of hydrogeologic factors, and leaks in a water line, sewer line, and roof drains, all of which were subsequently repaired. The eastern part of the property has a surficial layer of silt and/or clay. The lower permeability of these deposits, compared to the surrounding area, probably causes the ground-water head to build up. The leaky water line increased the head, which declined after the line was repaired.

Dewatering for a sewer project north of the landfill (adjacent to the river) is evident in Figure 8 (Appendix A). The water-table depression located near the northeast corner of the landfill is the result of several dewatering wells in the intermediate zone. The 10-foot head difference between the water table and intermediate zones is the result of pumping.

The potentiometric surface of the intermediate zone (about 40 to 80 feet below land surface) in August 1984 is depicted on Figure 9 (Appendix A). Ground-water flow in this portion of the unconsolidated deposits is toward the Mississippi River. Flow is being diverted in the area north of the landfill due to dewatering activities.

The potentiometric surface of the deep zone (80 to approximately 120 feet below land surface) in August 1984 is illustrated in Figure 10 (Appendix A). The elevation of the water levels and the ground-water flow patterns are similar to those of the intermediate zone.

3.2.2 November 1985

In contrast to low river stage (5 to 7 feet) in August 1984, the Mississippi River was 32 to 33 feet above the U.S. Army Corps of Engineers datum in November 1985. The effect of high river stage on the ground-water system is clearly demonstrated in Figures 11 through 14 (Appendix A).

The configuration of the water table in November 1985 (Figure 11, Appendix A) shows that the high river stage has caused a reversal in ground-water flow when compared to August 1984. Ground-water movement is away from the Mississippi River in response to a gradient which extends eastward to a ground-water divide located 3,500 feet from the river. Gradient reversal generally does not last longer than two weeks during flood conditions, therefore, constituents in ground water cannot travel very far before the gradient reverses itself again. A ground-water mound still exists under a portion of the plant area. Dewatering operations near the river were temporarily suspended due to the river level at the time of the water-level measurements.

The potentiometric surface of the intermediate zone for November 1985 is shown in Figure 12 (Appendix A). Ground-water flow in this zone is also easterly away from the river, for a distance of approximately 4,500 feet. A cone of depression is evident in the plant area, as a result of a dewatering project.

The potentiometric surface of the deep zone for November 1985 is shown in Figure 13 (Appendix A). The elevation of the water levels and the direction of ground-water flow are similar to those of the intermediate zone.

4.0 AQUIFER TESTS

4.1 Water-Table Zone

In November 1983, slug tests were conducted by Geraghty & Miller, Inc. in Wells GM-1, GM-2, and GM-3. The purpose of these tests was to determine aquifer transmissivity, hydraulic conductivity (permeability) and the storage coefficient in the uppermost saturated unit.

A weight of a known volume was lowered below the water level in each well, displacing the water column upward. Measurements of the water-level decline were made with an electric probe at 15-second intervals. The test began as soon as the weight was lowered below the water level in the well, and the test ended when the water level in the well had declined to the original pre-test static level. Water-level measurements and elapsed times are given in Table 7 (Appendix D).

The method used to analyze the slug test data was developed by Cooper, Bredehoeft, and Papadopoulos (Lohman, 1972). The technique is applicable to wells screened across the entire thickness of a confined aquifer of rather low transmissivity. If the tested well is screened across part of the aquifer, the transmissivity values only apply to that part of the aquifer in which the well is screened or open.

Table 8 (Appendix D) summarizes data for Wells GM-1, GM-2, and GM-3. The calculated hydraulic conductivities of the water-table zone ranged from 1.9 to 23 gallons per day per square foot (gpd/ft^2) and averaged $9.5 \text{ gpd}/\text{ft}^2$. The calculated transmissivity values ranged from 28.5 to $344.3 \text{ gpd}/\text{ft}$ and averaged $141.5 \text{ gpd}/\text{ft}$. These values may be somewhat higher than the actual transmissivities because of the effect of the gravel pack around portions of the well screens.

4.2 Intermediate Zone

Schicht (1965) provided aquifer test data for six sites in Madison and St. Clair Counties (Table 10, Appendix D). Three of these tests were performed on wells which most likely tap the intermediate zone (Olin Mathieson Chemical Corporation, City of Wood River, and the Southwestern Campus of Illinois University, Edwardsville). Mean transmissivity and permeability values were determined to be 120,200 gpd/ft and 1,620 gpd/ft², respectively. The storage coefficients were representative of water-table conditions, as they ranged from 0.020 to 0.155.

John Mathes & Associates, Inc. conducted an aquifer test in September 1983 in the intermediate zone on Monsanto property. The purpose of the test was to determine well size, well spacing and discharge rates that would be required to complete the new main south trunk sewer in the plant area.

The aquifer test was carried out in an existing 18-inch diameter well, 65 feet deep, located adjacent to the ACL Building (near Well DW-5) in the plant area. The well was pumped for 48 hours at a rate which varied during the early portion of the test, but stabilized at 715 gpm during the last 24 hours of the testing period. Nine observation wells were monitored during the test.

Geraghty & Miller, Inc. evaluated the aquifer test data and determined the following aquifer characteristics of the intermediate zone: Transmissivity = 165,000 gpd/ft, hydraulic conductivity = 3,300 gpd/ft², and storage coefficient = 0.04.

4.3 Deep Zone

Table 10 (Appendix D) also provides hydrogeological characteristics of the deep zone, specifically, transmissivity, permeability, and storage coefficient values, for sites at Shell Oil Company, Mobil Oil Company and Monsanto. The aquifer test performed in 1952 on a Monsanto test well was located near Ranney Well No. 3. The saturated thickness of the aquifer, at the time of the aquifer tests, varied from 73 feet on Mobil's property to about 100 feet at Shell Oil Company, about three miles to the northeast. Mean transmissivity and permeability values were

calculated to be 211,000 gpd/ft and 2,600 gpd/ft², respectively. The coefficient of storage represents water-table conditions for the Mobil site (0.100) and at Monsanto (0.082); however, a value of 0.002, indicative of artesian conditions occurs at the shell Oil Company site.

5.0 GROUND-WATER VELOCITY

5.1 Water-Table Zone

Ground-water velocity in the water-table zone was determined using the following form of Darcy's Law

$$V = \frac{KI}{xn}$$

where:

V = velocity, in feet per day

K = hydraulic conductivity of the deposits in the direction of flow, in gallons per day per square foot

I = hydraulic gradient, in feet per foot

n = effective porosity, which is dimensionless (Walton, 1984)

x = 7.48 gallons per cubic foot

To compute the velocity value, the following data were used: the average hydraulic conductivity value obtained during Geraghty & Miller, Inc.'s aquifer testing of the shallow zone (9.5 gpd/ft²); the hydraulic gradient (0.0025) which was measured in an area on the August 1984 water-table map (Figure 8, Appendix A) unaffected by either mounding or pumping conditions; and an assumed effective porosity of 15 percent which was estimated from the range (10-30) given for fine sand by Walton (1984). Because the water table zone consists of silty sand, a value at the low end of the range was chosen. The calculated velocity is 0.02 feet per day (7.3 feet per year) for the upper 15 feet of the saturated zone.

5.2 Intermediate Zone

Ground-water velocity in the intermediate zone of the Henry Formation was also calculated using Darcy's Law. The hydraulic conductivity (3,300 gpd/ft²) was obtained by dividing the transmissivity of this zone (obtained from the John Mathes & Associates, Inc. aquifer test - 165,000 gpd/ft) by its saturated thickness (50 feet). This method should provide a minimum permeability as the pumping well is screened over only a portion of the aquifer. The data from

Table 10 (Appendix D) were not used because all three tests were conducted in Madison County. The hydraulic gradient (0.0020) was determined from the August 1984 water-level map in areas unaffected by dewatering operations (Figure 9, Appendix A). The effective porosity was assumed to be 20 percent (Walton, 1984). Therefore, the calculated ground-water velocity is 4.4 feet per day (1,606 feet per year).

5.3 Deep Zone

Ground-water velocity in the deep zone was determined to be 6.4 feet per day (2,350 feet per year). The hydraulic conductivity ($4,200 \text{ gpd/ft}^2$) was determined by dividing the transmissivity value obtained during the 1952 aquifer test (Table 10, Appendix D) by the saturated thickness of 50 feet (90 to 140 feet below land surface). This value is higher than the permeability listed in Table 10 of Appendix D ($2,800 \text{ gpd/ft}^2$) because Schicht (1965) used 75 feet as the saturated thickness, rather than 50 feet. The hydraulic gradient (0.0023) was determined from the August 1984 water-level map in areas unaffected by dewatering operations (Figure 10, Appendix A). The effective porosity was assumed to be 20 percent (Walton, 1984).

6.0 GROUND-WATER QUALITY

A summary of ground-water quality conditions for 1983 through 1986 and for 1986 through 1994 is presented below.

6.1 Summary for 1983 to 1986

Ground-water sampling programs have been conducted at the Monsanto facility since November 1983 (Tables E-1 through E-5 in Appendix E). The overall objective of the monitoring programs was to characterize plant-wide ground-water quality. A minimum of two samples were collected from wells in critical areas. However, some wells have been sampled only once while others, such as GM-12A, were sampled frequently for quality assurance/quality control purposes.

Between November 1983 and May 1984, three rounds of samples were collected from the first 12 wells installed by Geraghty & Miller, Inc. The fourth sampling round was conducted in June 1984, when ten wells in the landfill area were sampled. Each ground-water sample collected during the four sampling rounds was analyzed for USEPA priority pollutant compounds, with the exception of February 1984. Only total organic carbon (TOC), total organic halogens (TOX), total phenols and chloride were scheduled for this round. In addition to the priority pollutant analyses, TOC and TOX were determined in November 1983 and May 1984, and chloride was analyzed in the May 1984 program. Temperature, pH, and specific conductance (field parameters) were measured in the field during each round. Envirodyne Engineers (St. Louis, Missouri) provided the laboratory services for each of these sampling programs.

In August 1984, a plant-wide sampling program was initiated by Geraghty & Miller, Inc. after additional wells were installed between June and August, 1984. The analytical program included a library search for non-priority pollutant compounds in addition to the USEPA Priority Pollutants. Miscellaneous constituents, such as TOC, chloride, and total dissolved solids (TDS), were also included in the program, as well as the three routine field parameters. In addition, three wells were selected for dioxin analysis (GM-16A, GM-27B, and GM-28B). Envirodyne Engineers, Inc. also provided the laboratory services for this sampling program.

The analytical data for many samples collected during the August 1984 sampling round may be invalid because samples were held beyond the method holding times prior to analysis. Where there were questions regarding the integrity of the analytical data, wells were resampled in November 1985. The questionable data are reported but are footnoted in the data tables.

Based on the results of the September 1984 library search and Monsanto's knowledge of past chemical usage in the plant, a list of non-priority pollutant compounds was developed for addition to the priority pollutant list. These compounds could theoretically be present in the ground water and were analyzed for in sampling rounds after September 1984. The chemicals are listed below.

Volatile Organic Compounds

- Methyl-iso-butyl ketone
- Methyl-isoamyl ketone
- m-Xylene
- o-Xylene
- p-Xylene

Acid Extractable Organic Compounds

- 4-Chlorophenol

Base/Neutral Extractable Organic Compounds

- 2-Nitroaniline
- 4-nitroaniline
- 2-Nitrochlorobenzene
- 4-Nitrochlorobenzene
- 2,4-Dinitrochlorobenzene
- 3,4-Dinitrochlorobenzene
- 4-Nitrodiphenylamine
- Triphenyl phosphate
- 2-Nitrobiphenyl (Wells GM-8 and GM-31ABC only)
- 4-Nitrobiphenyl (Wells GM-8 and GM-31ABC only)

Five sampling rounds were conducted between November 1984 and February 1986 for the USEPA priority pollutant compounds on the site-specific list of non-priority pollutants. Environmental Testing and Certification (ETC) in Edison, New Jersey provided the laboratory services for each of these programs and their results are presented in Tables E-1 through E-5 (Appendix E).

The chemical data is extensive and would prove cumbersome to those not familiar with it. In order to present these data in a manner that will easily demonstrate where chemical constituents have and have not been detected, mean concentrations of total priority pollutants and identified non-priority pollutants have been calculated for each well. The organic fractions of the chemical analysis (i.e., volatile, base/neutral, acid and pesticide/PCB compounds) were averaged individually and the mean value for each organic fraction was added together (Table 11, Appendix D). The results of the data reduction are presented for each of the three hydrogeologic zones, and are shown in Figures 23 through 25 (Appendix A).

Laboratory results that are reported with a less than symbol (<) indicate the chemical constituent was not detected above its detection limit (the value to the right of the symbol) at the time the analysis was performed. These results were assigned to a value of zero for computations of means or averages. The detection limits for the same compounds vary between Envirodyne and ETC, as well as between sampling events analyzed by the same laboratory. This is due to different analytical equipment, the volume of sample analyzed and different levels of interferences.

The results of the USEPA priority pollutant metals analysis for each sampling round are provided in Table E-5 in Appendix E. Most results are below the method detection limits, and few analyses are above USEPA drinking water standards for the metals that were detected. Therefore, these data are presented only in tabular form.

Throughout the course of the ground-water sampling programs conducted at the W.G. Krummrich Plant, 10 to 15 percent of the total number of samples were submitted as blind replicates, and trip and field blanks were also collected for QA/QC purposes. The blanks were analyzed for volatile organic compounds only. Replicates from Well GM-12A were collected during each sampling round, except September 1984, to provide a continuing check on laboratory performance.

With the exceptions of the September and November 1984 field blanks, trip blanks collected in May and September 1984 and five laboratory blanks collected in September 1984 (11 out of a total of 34), total volatile organic compound concentrations were less than 50 micrograms per liter ($\mu\text{g/L}$) in the blanks (see Table E-1). Benzene, chlorobenzene, and methylene chloride were compounds present in the highest concentrations in the blanks, with methylene chloride constituting more than 50 percent of the total in most cases. Because these compounds were found in all three types of blanks which are made up from distilled/deionized water provided by the laboratory and these compounds are used for many purposes in the laboratory (especially methylene chloride which is a solvent and extractant), the presence of contaminants in the blanks is regarded as a laboratory artifact. A detailed evaluation of the quality of the laboratory data is provided in the 1986 hydrogeologic study prepared by Geraghty & Miller.

6.2 Conclusions

The following conclusions were prepared by Geraghty & Miller in 1986 with respect to the W.G. Krummrich Plant.

6.2.1 Off-Site Impacts

Despite the fact that plant operations have affected ground-water quality, the off-site impact is minimal. The prevailing ground-water flow direction in all three hydrogeologic zones is westward toward the Mississippi River which is the ultimate point of discharge. Once in the Mississippi River, the concentrations of the constituents are diluted below detectable limits.

Geraghty & Miller, Inc.'s 1986 inventory of off-site wells and analysis of the water-table and potentiometric surface maps indicate that there are no off-site potable supply wells in the area. The only wells presently being pumped in the vicinity of the Monsanto property are being used for industrial or dewatering purposes and not for drinking water supplies. Water-level maps show that flow is toward the river and no cones of depression, which would be manifested by a circular pattern of equi-potential lines, can be seen within Monsanto's property boundaries. In all likelihood, constituents that may have originated from sources on the Monsanto property never migrated offsite in any direction other than to the west. Prior to 1973, constituents were probably captured in the cones of depression created by the on-site pumping. Between 1973 and 1980, the flow direction shifted toward the west and all ground water now migrates toward the Mississippi, with the exception of short time periods during flood conditions.

6.2.2 Sources of Contamination

It is most likely impossible to attribute the presence of specific compounds (or concentrations) in ground water to individual sources within the plant because of the potentially diverse number of points of origin. Leaky sewers, former leaky underground storage tanks, old spills and other discharges to the ground are all potential sources of ground-water contaminants. Changes in ground-water flow direction as a result of changes in pumpage over the years, temporary reversals of gradient at high river stage, and the dewatering operations conducted in the 1980s for the sewer system have mixed plumes from the various sources.

It is possible that some compounds are originating on adjacent properties and could contribute to the overall problem. The occurrence of benzene, toluene and xylene in wells of cluster GM-12, for instance, may indicate contamination which originates from the east.

The origin of organic compounds in the small zone in the southwest corner of the property is attributed to the former Route 3 drum site. Organic compounds are present in Well GM-31A which is downgradient of the drum area. Well GM-8 is upgradient and shows a low volatile organic compound concentration of 44 µg/L. Organic compound concentrations are below 100 µg/L in the intermediate zone.

The ground-water impact of the Route 3 drum area appears to be limited because the shallow zone is the only zone that has been affected. Organic compounds in the shallow zone have probably not traveled westward (downgradient) more than about 300 feet, even if the conservative movement (at the same rate as the average ground-water flow velocity), it is assumed. The estimate of the migration distance is based on the fact that the former drum site has been in existence approximately 40 years (as of 1986) and that ground water in the shallow zone moves at about 7 feet per year.

The intermediate zone in the vicinity of the Route 3 drum area does not appear to have been affected and this is consistent with the head data for well cluster GM-31. These data indicate that there is a very small downward hydraulic gradient which could drive constituents in the shallow zone into the deeper zones.

6.3 Recommendations

The following recommendations were prepared by Geraghty & Miller in 1986 with respect to the W.G. Krummrich Plant.

6.3.1 Remedial Action

Remedial action with respect to ground-water contamination itself appears to be unnecessary. Creating a hydraulic barrier to prevent the off-site ground-water migration of contaminants, for instance, is unjustifiable because there is no public health or environmental impact offsite. The potential for exposure to contaminated ground water should lessen with time because the use of the aquifer in the Sauget area will continue to decline in favor of river water use.

Another important reason for not recommending a ground-water cleanup program is that the reduction of concentrations of organic compounds to low levels is impractical. The area affected by organic compounds is quite large and ground-water contamination, therefore, must be

regarded on a regional scale. Cleanup would require pumpage of large quantities of water from the intermediate and perhaps the deep zones. The permeability of the shallow zone is so low that a tubular well pumping system is not feasible.

Given the large volumes of ground water to be recovered, it would be necessary to essentially operate the pumping system for an indefinite period of time. For instance, the volume of contaminated water in the zones where organic compound concentrations are above 100 µg/L beneath the plant and in the central area of the property is estimated at 8×10^8 gallons, assuming the effective porosities for each zone given in Section 5.0. In order to reduce the contaminant concentrations to 20 to 30 percent of their original concentrations, the aquifer pore volume would probably have to be exchanged about 150 times (Gillham, 1982). This represents a total volume of approximately 1.2×10^{11} gallons. A recovery system pumping at 1,000 gallons per minute would require approximately 200 years to accomplish this task. Establishing such a pumping system would be neither feasible nor cost effective.

Because the shallow zone cannot be pumped with wells, a passive system, such as a collector trench, would be required. The most likely position for a trench is immediately west of Route 3. Even if the collector system could double the hydraulic gradient, which is unlikely, and, in turn, reduce the constituent travel time by half, organic compounds which are now in the central plant area would take approximately 100 years to arrive at the collector system.

In order to alleviate ground-water contamination in the most cost-effective manner, Monsanto should continue with its policy of eliminating potential sources. The projects that have already been completed, are now underway, and those anticipated in the near future (as of 1986) should significantly reduce the contaminant loading to the ground-water system.

Projects that have been completed to date at a total cost of about \$2 million consist of the following.

- Powerhouse Sewer Main: The powerhouse sewer main was repaired and replaced in 1985.

- Building BK Projects: Sewer, roof drain, and process water leak repairs to underground piping were completed in the vicinity of the BK office building. These were indicated by a ground-water mound in the BK building area during ground-water mapping. The projects were completed in 1985.
- Riverbank Erosion Control: Project work for erosion control of the riverbank property, which is adjacent to Monsanto's landfill, commenced in 1983. The project was completed in early 1986 after approximately 90,000 tons of rock and sand was placed on the 2,300 linear footage of the riverbank.
- South Lot Drum Site: Thirty drums of chemical waste, which were exhumed during a recent construction project, were removed from the ground in July 1986.

A major project to repair the sewer system in the community is underway and is expected to be completed in about three years. Two thousand linear feet of sewer piping is being replaced on the Monsanto property and the project is estimated to be completed in 1987 at a cost of \$7 million. The sewer system in the Village of Sauget is being repaired and upgraded, and upon completion in 1989, will have cost about \$21 million. Replacement and repair of the sewer should result in an improvement in ground-water quality because the old system is suspected of being a major source of contaminant loading to the ground water.

Geraghty & Miller, Inc., in a recent report, has recommended a clay cap for the Route 3 drum site. This report describes a boring program that was undertaken at the Route 3 drum site, characterizes the geology and reviews the remedial alternatives that were considered for the Site. The report also contains the data upon which the recommendation for the cap is based.

6.3.2 Ground-Water Monitoring

Geraghty & Miller, Inc. has formulated a ground-water monitoring program for the Monsanto Company property to determine whether water quality is changing significantly over time. In order to maximize the reliability of the data, Geraghty & Miller, Inc. believes it is necessary to include only those wells that have documented well construction details. In addition, the wells selected for this program should be limited to those near property boundaries, wells downgradient

of the landfill, and in the vicinity of the Route 3 drum site which is located between well cluster GM-31 and Well GM-8. The monitoring wells that have been selected for this program are included in Table 19 (Appendix D) and shown in Figure 23 (Appendix A).

At present there is insufficient data to determine concentration trends. Geraghty & Miller, Inc.'s experience indicates that at least 10 to 12 samples over 3 to 5 years are needed to obtain a trend significant at the 95 percent confidence level. Monsanto should establish a program to obtain the required data. Semi-annual samples should be sufficient because, in 1989, after five years of monitoring, 11 sets of data will be available for a trend analysis.

The list of chemical parameters that should be evaluated for each well will vary because the distribution of specific groups of compounds (e.g., volatile organic compounds) varies from one area of the plant property to another. For example, for each well in the plant process area where VOCs have been detected, the occurrence of USEPA extractable organic compounds is usually less common, and pesticides/PCBs are rarely found. Therefore, for the purpose of monitoring ground-water quality over time, it is not necessary to analyze for some fractions of USEPA priority pollutants and nonpriority pollutant organic constituents.

7.0 DESIGN AND IMPLEMENTATION OF THE GROUND-WATER MONITORING PROGRAM

In September 1986, Geraghty & Miller designed a semiannual ground-water monitoring program for Monsanto to determine whether water quality was changing (Table 19, Appendix D). This program was described in Geraghty & Miller's 1986 report which assessed the ground-water conditions at the W.G. Krummrich plant. Monsanto authorized the program to proceed in December 1986. The monitoring program included 18 wells in the production area and Lot F and 11 wells at Lot H. The parameters selected for the program varied from well to well as only those constituents previously detected (based on two sampling rounds) were included. Since neither pesticides, PCBs, nor metals were a concern in ground water at the Site, the monitoring program did not include these constituents.

8.0 MODIFICATIONS TO THE GROUND-WATER SAMPLING PROGRAM

The frequency and number of wells sampled semiannually were revised by Geraghty & Miller in May 1989 after five sampling rounds of data had been evaluated. The program was initially scheduled to be reviewed in 1991 after five years (or ten rounds) of data had been collected. However, since ground-water quality data were available from five sampling rounds and ground water moves very slowly (7.3 ft/yr) in the water-table zone, semiannual sampling was deemed to be unnecessary and the sampling for the shallow monitoring wells was rescheduled to be on an annual basis, with the exception of the upgradient shallow well GM-12A. The monitoring wells in the intermediate zone and deep zone in Lot F (GM-4B, GM-4C, GM-17B, and GM-17C) and the upgradient wells (GM-12B and GM-12C) were sampled semiannually through 1991. Side gradient wells in the intermediate and deep zones (GM-9B, GM-9C, GM-10B, and GM-10C) were also selected for annual sampling in May 1989. The voluntary monitoring program is currently being conducted on an annual basis and is ongoing.

Of the four monitoring wells located downgradient of the Route 3 drum site, two shallow monitoring wells (GM-58A and GM-59A) are on Monsanto property and a well cluster consisting of one shallow and one intermediate well (GM-54A and GM-54B, respectively) is located on Village of Sauget property. These wells were initially sampled in November 1987. After two rounds of data had been obtained from the shallow well (GM-54A) on village property, this well was deleted from the program because the results indicated that ground water had not been impacted. The remaining three wells were sampled semiannually during 1987 and 1988 and then annually from 1987 to 1994. The three-well monitoring cluster located at the downgradient boundary of the Route 3 drum site was deleted from the program after the May 1991 sampling round. Sampling shallow well GM-31A was not necessary because drum-site-related compounds were known from prior sampling of this shallow well, and wells GM-58A and GM-59A were farther downgradient and still being monitored. Since drum-site-related compounds were not being detected in the deeper wells (GM-31B and GM-31C) and a downward gradient was not present, these two wells were also deleted from the program.

Other wells such as wells GM-5, GM-6A, and GM-B were sampled occasionally to provide information at specific locations; these wells were sampled in November 1992. Also in 1992, 12

wells were analyzed for Appendix IX compounds rather than the usual analytes, which consist of priority pollutant compounds plus site-related compounds. These 12 wells included an upgradient three-well cluster (GM-12A, GM-12B, and GM-12C) and nine wells in Lot F (GM-4A, GM-4B, GM-4C, GM-5, GM-6A, GM-6B, GM-17A, GM-17B, and GM-17C). The purpose of selecting wells upgradient and downgradient of the main plant area was to determine if any Appendix IX compounds were present in ground water either migrating onto the property or leaving the main plant area.

9.0 GROUND-WATER QUALITY IN 1992

In November 1992, as part of the annual monitoring program, ground-water samples were collected from 23 wells in the plant area, on Lot F, and in several locations on Village of Sauget property. The wells sampled and the list of analytical parameters are provided in Tables 1 and 2 (Appendix F). Data from the 14 wells sampled at Lot H will not be evaluated in this report because that site is being investigated separately by IEPA. The results from the November 1992 sampling round were added to the site ground-water database, which is provided Appendix G. As described in Section 8.0, 12 wells were selected for analysis of Appendix IX compounds, rather than the priority pollutant list, to determine if other compounds besides the priority pollutant and site-related compounds are present in the ground water. Based on the analytical results from the upgradient well cluster (GM-12A, GM-12B, and GM-12C) and the nine downgradient wells in Lot F, no additional compounds were found.

9.1 Water-Table (Shallow) Zone

Ground-water quality data for the water-table (shallow) zone are provided in Appendix G. In wells where duplicate samples were collected, the mean data are presented in Figures 3, 4, and 5 (Appendix B). An evaluation of VOCs, acid extractable organic compounds, and base neutral extractable organic compounds that are present in the water-table zone in 1992 is provided below.

9.1.1 Volatile Organic Compounds

VOCs, specifically benzene and chlorobenzene, are the compounds in ground water at the Site detected most frequently and in the highest concentrations. The analytical results for the monitoring program are provided in Appendix G (Table 1) and total VOCs for each well sampled in November 1992 are presented in Figure 3 (Appendix B).

The direction of ground-water flow in the water-table zone is from east to west, which is consistent with historical ground-water flow (Geraghty & Miller, Inc. 1986a). Therefore, ground-water flow maps were not prepared for the Geraghty & Miller, Inc. 1993 report. VOCs in the water-table zone are present in upgradient well GM-12A at 1,039 µg/L (average of duplicate analyses), well GM-9A (2,873 µg/L), and well GM-17A (904,400 µg/L). VOCs were not

detected in two wells in the northern portion of the Site (GM-4A and GM-10A) and VOCs were also not detected in downgradient well GM-5. The absence of VOCs in well GM-5 is important because this well is downgradient of the portion of the water-table aquifer that contains the highest VOC concentrations. The VOCs consist primarily of benzene and chlorobenzene, and these two compounds are found in many areas of the facility.

Well GM-31A is located at the downgradient boundary of the Route 3 drum site and was last sampled in November 1990. VOCs were reported to be present at 16 µg/L (average of duplicate sample results). Therefore, VOCs are not present in high concentrations in the source area. VOCs were not detected in downgradient well GM-59A, and 14 µg/L of chlorobenzene were detected in well GM-58A. Chlorobenzene is not a compound that is related to the drum site. Site-related compounds include phenols, nitrochlorobenzenes (NCB), dinitrochlorobenzenes (DNCB), and nitrobiphenyls (Geraghty & Miller, Inc., 1986b). Well GM-54A is located downgradient of the drum site on Village of Sauget property and was last sampled in May 1988 when methylene chloride was the only VOC detected at 34 µg/L. This analytical result may have been a laboratory artifact.

Based on the results presented above, it does not appear that VOCs are migrating offsite via the water-table zone.

9.1.2 Acid Compounds

Acid compounds are generally not found in high concentrations at this Site (Appendix G, Table 2). In upgradient well GM-12A, 162 µg/L of 2-chlorophenol (average of duplicate analyses) was detected in November 1992 (Figure 3). Due to the absence of these compounds in wells GM-9A and GM-10A prior to 1986, this group of compounds was not included in the monitoring program for these two locations. Acid compounds were found in downgradient well GM-6A (2-chlorophenol at 19 µg/L) and in well GM-17A (2-chlorophenol at 26 µg/L and phenol at 13 µg/L); however, acid compounds were not detected in either GM-4A or GM-5.

In the vicinity of the Route 3 drum site, acid compounds were not detected in wells GM-58A or GM-59A in 1992, nor were they detected in well GM-54A, which was last sampled in May 1988. These compounds were detected at 358 µg/L in well GM-31A (average of duplicate results) in November 1990, which was the last time the well was sampled.

Based on the results presented above, it does not appear that these compounds are migrating offsite via the water-table zone.

9.1.3 Base Neutral Compounds

Base neutral compounds (1,2-dichlorobenzene and aniline) were found at 2,254 µg/L (average duplicate analyses) in upgradient well GM-12A in November 1992 (Figure 3, Appendix B). The monitoring program's results are provided in Appendix G (Table 3). Due to the absence of these compounds in wells GM-9A and GM-10A prior to 1986, this group of compounds was not included in the monitoring program for these two locations. Base neutral compounds (1,2-dichlorobenzene and 1,4-dichlorobenzene) were found in downgradient wells GM-6A and GM-17A; however, base neutral compounds were not detected in either downgradient well GM-4A or downgradient well GM-5.

In the vicinity of the Route 3 drum site, base neutral compounds were detected at 3,377 µg/L in well GM-31A (average of duplicate analyses), which was last sampled in November 1990. Base neutral compounds were not found in well GM-59A, but 40 µg/L of 2-nitrochlorobenzene was detected in well GM-58A. Since this compound is related to the Route 3 drum site, it has likely migrated from that location. Well GM-54A was last sampled in May 1988 and base neutral compounds were not detected.

Based on the results presented above, the only area of the site where base neutral compounds may be migrating offsite is downgradient of the Route 3 drum site.

9.2 Intermediate Zone

Ground-water quality data for the intermediate zone are provided in Appendix G. Where duplicate samples were collected, mean data are presented in the figures. An evaluation of the VOCs, acid compounds and base neutral compounds are present in the intermediate zone in 1992 is provided below.

9.2.1 Volatile Organic Compounds

VOCs, specifically benzene and chlorobenzene, are the compounds most frequently detected in the intermediate zone and in the highest concentrations. The monitoring program's results are provided in Appendix G (Table 1) and total VOCs for each intermediate well sampled in November 1992 are presented in Figure 4 (Appendix B). VOCs are present in this zone in upgradient well GM-12B at 781 $\mu\text{g/L}$ (average of duplicate analyses), as well as in all other intermediate zone wells. Based on the results shown in Figure 4 (Appendix B), it appears that the area of impacted ground water terminates near the western boundary of Lot F due to 34 $\mu\text{g/L}$ of VOCs (primarily chlorobenzene in well GM-18B) and 20 $\mu\text{g/L}$ of VOCs (chlorobenzene only) in off-site well GM-20B. Since well GM-20B is in the vicinity of the Village of Sauget primary treatment plant, it is not clear whether an off-site source has impacted ground water in the vicinity of well GM-20B.

In the vicinity of the Route 3 drum site, VOCs were detected in well GM-31B at 133 $\mu\text{g/L}$ (primarily benzene and chlorobenzene) which was last sampled in May 1991. VOCs were also detected in off-site well GM-54B at 120 $\mu\text{g/L}$ which represented only benzene and chlorobenzene. Since VOCs represented only about 0.01 percent of the total organic concentration in shallow well GM-31A (Figure 3, Appendix B), it is likely that the VOCs detected in intermediate zone wells GM-31B and GM-54B are representative of relatively ubiquitous levels of VOCs (especially benzene and chlorobenzene) in the intermediate zone and they are probably not from the Route 3 drum site, which is covered with a RCRA cap. In addition, historical water-level data for the GM-31 and GM-54 well clusters indicate that neither a downward nor an upward head gradient exists in this area of the site. Without a downward driving force, there is no mechanism to move chemicals downward and into the intermediate zone.

The intermediate and deep hydrogeologic zones have been affected in the past by large withdrawals of ground water by local industrial supply wells. Ground-water flow maps that depicted past flow conditions have been provided by Geraghty & Miller's 1986 report, which demonstrated cones of influence around industrial locations in the Sauget area (Geraghty & Miller, Inc., 1986a). Pumping large quantities of water from the deep zone most likely drew the chemicals from the shallow depths into the intermediate and deep zones. The presence of constituents in these zones may be the result of past pumping practices. A more detailed description of historical flow conditions can be found in the 1986 report (Geraghty & Miller, Inc., 1986a).

Based on this information, the terminus of the VOC plume appears to be in the vicinity of the western boundary of Lot F.

9.2.2 Acid Compounds

The monitoring program's results are presented in Appendix G (Table 2) and concentrations for total acid compounds for each intermediate well sampled in November 1992 are presented in Figure 4 (Appendix B). Acid compounds were not detected in upgradient well GM-12B in November 1992 nor in downgradient well GM-20B. Relatively low levels of acid compounds were reported in downgradient wells along Route 3. Acid concentrations were detected in well GM-4B at 62 µg/L (2-chlorophenol), in well GM-6B at 17 µg/L (2-chlorophenol and 2,4-dichlorophenol), and in well GM-17B at 13 µg/L (2-chlorophenol). The only other acid compound detected at the site was phenol in GM-18B at 2 µg/L.

At the Route 3 drum site, acid compounds were not detected in either well GM-31B (last sampled in February 1985) or in well GM-54B.

Based on the data presented above, it does not appear that acid compounds are a concern in the intermediate zone.

9.2.3 Base Neutral Compounds

The monitoring program's results are presented in Appendix G (Table 3) and concentrations for total base neutral compounds for each intermediate well sampled in November 1992 are presented in Figure 4 (Appendix B). Base neutral compounds were not detected in upgradient well GM-12B in November 1992, nor in downgradient well GM-20B. Along Route 3, concentrations ranged from 242 to 2,553 µg/L for total base neutral compounds. These concentrations consisted predominantly of chloroanilines and dichlorobenzenes. At downgradient well GM-18B, 31 µg/L of total base neutrals were reported; however, 28 µg/L of this total was bis(2-ethylhexyl)phthalate, which is often a laboratory artifact.

At the Route 3 drum site, base neutral compounds were detected in GM-31B (last sampled in November 1985) at 45 µg/L which only consisted of bis(2-ethylhexyl)phthalate, a potential laboratory artifact. In well GM-54B, base neutral compounds were detected at 229 µg/L in November 1992 and this result consisted only of chloroaniline compounds. These compounds were not on the parameter list for the November 1985 sample collected from GM-31B, therefore, it is not clear whether a relationship exists. The chloroaniline compounds are present in other areas in the intermediate zone and these compounds are not related to the Route 3 drum site. The presence of the chloroaniline compounds at this location may be due to another source because a downward head gradient does not exist in this area of the site.

Based on the results presented above, the only area of the site where site-related base neutral compounds may be migrating offsite is at the Route 3 drum site.

9.3 Deep Zone

Ground-water quality data for the deep zone are provided in Appendix G. Where duplicate samples were collected, mean data were presented in the figures. An evaluation of the VOCs, acid compounds, and base neutral compounds that are present in the deep zone in 1992 is provided below.

9.3.1 Volatile Organic Compounds

VOCs, specifically benzene and chlorobenzene, are the compounds detected most frequently and in the highest concentrations in the deep zone. The analytical results of the monitoring program are provided in Appendix G (Table 1) and total VOCs for each deep well sampled in November 1992 are presented in Figure 5 (Appendix B). VOCs are present in this zone in upgradient well GM-12C at 13 µg/L (chlorobenzene), as well as in all other deep zone wells. The results shown for wells GM-9C, GM-10C, and GM-31C consist only of benzene and chlorobenzene and are all much lower in concentration than in the intermediate zone. However, the results for wells GM-4C and GM-17C are considerably higher, especially at GM-4C. The higher results in the deeper zone are not consistent with ground-water flow because a downward gradient does not exist between the intermediate and deep zones. However, as discussed earlier in this report, past ground-water withdrawals may be responsible for drawing these chemicals down into the deep zone.

In the vicinity of the Route 3 drum site, VOCs were detected in well GM-31C at 57 µg/L (chlorobenzene only) which was last sampled in May 1991. Since this well is screened from 97 to 117 feet below grade, it is unlikely that the chlorobenzene is related to the drum site especially since a downward gradient is not present. In addition, chlorobenzene is not one of the compounds related to the drum site, and it appears to be relatively ubiquitous throughout the area.

Based on the results shown in Figure 5 (Appendix B), it cannot be determined whether VOCs are migrating offsite through the deep zone.

9.3.2 Acid Compounds

The monitoring program's results are provided in Appendix G (Table 2) and the concentrations for total acid compounds for each deep well sampled in November 1992 are presented in Figure 5 (Appendix B). Acid compounds (predominantly 2-chlorophenol) were detected at 6 µg/L in upgradient well GM-12C and at slightly higher concentrations along Route 3. Acid

concentrations were reported in well GM-4C at 24 µg/L (2-chlorophenol) and in well GM-17C at 52 µg/L (2-chlorophenol and 2,4-dichlorophenol). These results are similar to the results presented for the intermediate zone wells.

At route 3 drum site, acid compounds were reported at 6 µg/L (2-chlorophenol) in well GM-31C which was last sampled in November 1985 (duplicate analyses).

Based on the data presented above, it does not appear that acid compounds are a concern in a deep zone.

9.3.3 Base Neutral Compounds

The monitoring program's results are presented in Appendix G (Table 3) and concentrations for total base neutral compounds for each deep well sampled in November 1992 are presented in Figure 5 (Appendix B). Chloroanilines and dichlorobenzenes are the major base neutral compounds found in the deep zone. Base neutral compounds were found in upgradient well GM-12C at 36 µg/L (1,2-dichlorobenzene) and in higher concentrations in downgradient wells along Route 3. Total base neutral compounds (predominantly dichlorobenzenes and chloroanilines) were found in wells GM-4C and GM-17C at concentrations of 3,704 µg/L and 880 µg/L, respectively. These results differ considerably from the intermediate zone wells as the concentrations in well GM-4C are much higher than the intermediate zone data, and the results for GM-17C are much lower than the intermediate zone concentrations. These differences may be the result of past pumping in the deep zone.

At the Route 3 drum site, bis(2-ethylhexyl)phthalate was detected in one of the duplicate samples collected at well GM-31C at 84 µg/L but not in the other. Since averaged results were plotted on all the chemical distribution maps, a result of 42 µg/L was plotted for this location. Since this compound is often reported as a laboratory artifact, the chemical may not be present in ground water at this location.

Based on information presented above, it is not clear whether base neutral compounds are migrating offsite through the deep zone.

10.0 GROUND-WATER QUALITY TRENDS

Since December 1986, ground water at the site has been monitored to determine whether its quality has been changing over time. Upgradient, side gradient, and downgradient wells have been sampled regularly, and the analytical results are discussed in this section of the report. With the exception of the Route 3 drum site, benzene and chlorobenzene have been selected as indicator compounds because these compounds comprise the largest percentage of the total organic concentrations in each of the wells monitored. At the Route 3 drum site, phenolic compounds, nitrochlorobenzenes, dinitrochlorobenzenes, and nitrobiphenyls, have been determined to be characteristic of this area based on water quality.

Contour maps of chemical constituents are a useful tool for depicting present site conditions and for identifying short-term changes because maps drawn for different data acquisition time periods can be compared. However, as it is not always easy to identify and understand long-term trends by comparing maps, indicators of water quality (such as benzene and chlorobenzene) have been compiled into graphs showing concentration versus time. These graphs are for the key wells currently being monitored or monitored in the past and are provided in Figures E-1 through E-20 in Appendix H. The graphs are from the 1993 Geraghty & Miller report and include data through 1992. The wells have been divided into the three hydrogeologic zones: Water-table (shallow) zone, intermediate zone, and deep zone. The trends discussed below are based on visual inspection of the historical data that are included in Appendix G.

10.1 Water-Table (Shallow) Zone

Well GM-12A is at the upgradient boundary of the site in the water-table zone, and benzene and chlorobenzene are the primary constituents in ground water at this location. Based on the results shown in Figure E-1 (Appendix H), it appears that the concentrations for both compounds have been higher in recent years and the concentrations have fluctuated considerably over time.

Well GM-9A is located at the plant's southern boundary and is hydraulically side gradient to the ground-water flow direction. Similar to upgradient well GM-12A, benzene and chlorobenzene concentrations have fluctuated considerably in the last four sampling rounds, as compared to the first few years of data when these compounds were barely detected at all (Figure E-2 in

Appendix H). Another side gradient well (GM-10A) is located near the site's northern boundary. In November 1990, 5,030 µg/L of benzene was reported in this well, but neither benzene nor chlorobenzene has ever been detected on any other occasion during the entire monitoring program (Figure E-3 in Appendix H). Based on these data, this result is considered to be an outlier.

Downgradient wells GM-4A and GM-17A are located on the west side of Route 3. Similar to the data discussed above, relatively low concentrations of benzene and chlorobenzene (5 to 21 µg/L) were detected in well GM-4A in 1989 and 1990 but neither compound was detected prior to or after those sampling rounds (see Figure E-4 in Appendix H). Elevated concentrations of benzene and chlorobenzene have been detected in downgradient well GM-17A (see Figure E-5 in Appendix H) since monitoring began, and there has been little improvement in water quality in this well over time.

At the Route 3 drum site, phenolic compounds have been compared to nitrochlorobenzenes, dinotrochlorobenzenes, and nitrophenyls. In well GM-31A, which is located at the downgradient boundary of the drum site, concentrations have been elevated throughout the monitoring period (see Figure E-5 in Appendix H). With the exception of the high concentrations of phenol in November 1988, a number of compounds appear to have been reported in higher concentrations after 1985, at which time the drum site was excavated to determine if the buried drums were still intact. After the site was capped with a RCRA cap in 1986, the concentrations of some of the compounds decreased.

Downgradient of the Route 3 drum site, wells GM-58A and GM-59A have been monitored since their installation in 1987. Although the total concentration of site-related compounds has been detected as high as 150 µg/L in well GM-58A (see Figure E-7 in Appendix H), the range of concentrations has been very low in comparison to well GM-31A, given the fact that GM-58A is less than 150 feet from GM-31A. At well GM-59A, site-related compounds were detected only

once (November 1988) at a total concentration of 53 µg/L (see Figure E-8 in Appendix H). Site-related compounds have not been detected in well GM-59A either before or after November 1988.

10.2 Intermediate Zone

Well GM-12B is at the upgradient boundary of the site in the intermediate zone, and total xylenes and benzene are the primary constituents in ground water at this location. Xylenes have not been found in downgradient well locations, but based on the sporadic detection of these compounds at the upgradient location, they appear to be migrating onto the site from the east. Based on the results shown in Figure E-9 (Appendix H), the concentrations for both compounds appear to have fluctuated considerably over time.

Well GM-9B is located at the southern boundary of the plant and is hydraulically side gradient to the ground-water flow direction. Benzene and chlorobenzene are the primary constituents in ground water at this location (see Figure E-10 in Appendix H). Benzene concentrations have been low through 1989 (from not detected to 11.9 µg/L); however, concentrations were higher during the last three sampling rounds (717 to 3,960 µg/L). The reason for this increase is unclear. Chlorobenzene concentrations have remained relatively constant during the monitoring period. Another side gradient well (GM-10B) is located near the northern boundary of the site. Benzene detections have been sporadic over time and at relatively low concentrations (see Figure E-11 in Appendix H). Chlorobenzene detections have also been sporadic over time; however, the data for the last two sampling rounds have been higher than for any other result for this well. The reason for the recent increase in chlorobenzene concentrations is not clear.

Downgradient wells GM-4B and GM-17B are located on the west side of Route 3. Benzene and chlorobenzene are the primary constituents in ground water at these locations.

In well GM-4B, benzene has been detected sporadically and at relatively low concentrations (see Figure E-12 in Appendix H). Chlorobenzene has been detected more frequently; however, its concentrations have also fluctuated considerably over time. In well GM-17B, benzene was

initially detected at high levels (50,000 to 70,000 µg/L); however, since May 1988, benzene has only been detected in 2 of 8 analyses at concentrations of 220 and 249 µg/L (see Figure E-13 in Appendix H). Chlorobenzene concentrations have fluctuated over time but are usually reported in the parts per million range.

At the Route 3 drum site, the primary constituents in the intermediate zone are not the acid and base neutral compounds identified for the water-table zone. Benzene and chlorobenzene are the primary constituents, and they are probably not related to the Route 3 drum site because (1) the intermediate zone well (GM-31B) is screened from 65.5 to 85.5 feet below land surface; (2) there is no downward vertical head gradient; (3) the acid and base neutral compounds are not present; and (4) benzene and chlorobenzene concentrations are relatively ubiquitous across the site. Benzene and chlorobenzene results are provided for well GM-31B on Figure E-14 (Appendix H). Benzene detections have been sporadic and at low concentrations (not detected to 16.6 µg/L). The chlorobenzene data represent an average of duplicate results for most of the sampling rounds. Chlorobenzene detections have also been sporadic, and the highest concentration of 193.5 µg/L is an average of 387 µg/L and a non-detect duplicate result. Therefore, the data set is questionable.

10.3 Deep Zone

Well GM-12C is at the upgradient boundary of the site in the deep zone, and few constituents have been detected in this well. Benzene was detected at 32.7 µg/L in May 1990, and chlorobenzene was detected at 13.2 µg/L in November 1992 (see Figure E-15 in Appendix H). Neither compound has been detected at any other time since the monitoring program began in December 1986.

Well GM-9C is located at the southern boundary of the plant and is hydraulically side gradient to the ground-water flow direction. Benzene and chlorobenzene are the primary constituents at this location (see Figure E-16 in Appendix H). Concentrations have fluctuated considerably over time, but results have been generally higher for each compound in recent years. Another side gradient well (GM-10C) is located near the northern boundary of the site. Benzene has not been detected since the monitoring program began in December 1986 (see Figure E-17 in

Appendix H). Chlorobenzene results have been very consistent over time at relatively low levels, with the exception of the November 1989 and November 1990 sampling rounds, when chlorobenzene was reported at 752 and 451 $\mu\text{g/L}$, respectively.

Downgradient wells GM-4C and GM-17C are located on the west side of Route 3. Chlorobenzene is the primary constituent in ground water at these locations, with benzene being detected only sporadically. In well GM-4C, benzene has been detected on 3 of 10 occasions at concentrations ranging from 190 to 693 $\mu\text{g/L}$ (see Figure E-18 in Appendix H). Chlorobenzene concentrations have been generally increasing over time. The reason for this apparent trend is unclear. In well GM-17C, benzene has been detected on 4 of 10 occasions at concentrations ranging from 22.5 to 390 $\mu\text{g/L}$ (see Figure E-19 in Appendix H). Chlorobenzene concentrations were high initially (6,000 to 21,000 $\mu\text{g/L}$), dropped to levels below 1 part per million, then increased in recent years to 6,000 to 7,000 $\mu\text{g/L}$. This fluctuation in chlorobenzene concentrations cannot be explained at this time.

At the Route 3 drum site, the primary constituents in the deep zone are not the semivolatile compounds found in the water-table zone, but are benzene and chlorobenzene, as was found in the intermediate zone. Benzene was detected on 5 of 10 occasions at concentrations ranging from 15.4 to 144 $\mu\text{g/L}$ (see Figure E-20 in Appendix H). Chlorobenzene fluctuated considerably and was detected on 7 of the 10 occasions at concentrations ranging from 52.7 to 1,120 $\mu\text{g/L}$. The highest concentrations were detected in November 1988 and May 1989, and the chlorobenzene concentrations dropped to 56.6 $\mu\text{g/L}$ in November 1992. As discussed above, we do not believe that the benzene and chlorobenzene concentrations detected in ground water have migrated into the intermediate and deep zones from the Route 3 drum site, which is located above the water table in the shallow zone.

11.0 COMPARISON OF 1984/1985 AND 1992 WATER QUALITY DATA

To determine if the plumes of impacted ground water within the water-table, intermediate and deep zones have stabilized, ground-water quality data from 1984/1985 were compared to data from 1992 by Geraghty & Miller in 1993. Because benzene and chlorobenzene concentrations are the constituents detected most frequently and in the highest concentrations, data for these two compounds from 1984/1985 and 1992 were compared within each zone. By examining both compounds, the effects of in-situ degradation can be evaluated because benzene is highly biodegradable whereas chlorobenzene is not. Duplicate results were averaged, and the comparison of water quality data for each zone, as provided by Geraghty & Miller in 1993, is provided below.

11.1 Water-Table (Shallow) Zone

Since most of the water-table monitoring wells were installed in 1983 and 1984, and many wells were first sampled in 1984, benzene and chlorobenzene data from 1984 were compared to 1992 concentrations to determine whether the plume identified in 1984 has stabilized.

Benzene concentrations for 1984 and 1992 have been plotted in Figure 6 (Appendix B). Since the monitoring wells at the Route 3 drum site were installed after 1984, the data for these wells are representative of the year each well was first installed. The benzene concentrations from the two data sets are very similarly for most wells, and a 100 µg/L contour line was plotted for both data sets. The red contour line represents 1992 data and the blue contour line represents 1984 data. The similar positions of the 100 µg/L contour lines for 1984 and 1992 suggests that the benzene plume has stabilized onsite.

Chlorobenzene concentrations for 1984 and 1992 have been plotted in Figure 7 (Appendix B). The data for the Route 3 drum site represent the year each well was installed. The chlorobenzene results for 1984 and 1992 and the positions of the 100 µg/L contour lines suggest that the chlorobenzene plume has stabilized onsite.

11.2 Intermediate Zone

Since most of the intermediate zone monitoring wells were installed by 1985, the initial benzene and chlorobenzene data from 1985 were compared to 1992 concentrations to determine whether the plume identified in 1985 has stabilized.

Benzene concentrations for 1985 and 1992 have been plotted in Figure 8 (Appendix B). Since well GM-54B (Route 3 drum site) was installed in 1987, the results from 1987 were plotted for this well. A 100 $\mu\text{g/L}$ contour line was plotted for both data sets to identify the area where the greatest impacts to ground water have occurred. A comparison of the benzene concentrations indicates a general improvement of water quality between 1985 and 1992. Specifically, a decrease in concentrations to non-detectable levels at four downgradient wells (GM-6B, GM-17B, GM-18B, and GM-20B), and at side gradient well GM-10B. The similar positions of the 100 $\mu\text{g/L}$ contour lines for 1985 and 1992 suggest that the benzene plume has stabilized onsite.

Chlorobenzene concentrations for 1985 and 1992 have been plotted in Figure 9 (Appendix B). As discussed above, 1985 data were not available for well GM-54B because this well was installed in 1987; therefore, 1987 data were plotted. A comparison of the chlorobenzene concentrations indicates a general improvement of water quality between 1985 and 1992. Specifically, a decrease in concentrations at five downgradient wells (GM-4B, GM-6B, GM-18B, GM-20B, and GM-31B) and at side gradient well GM-9B. The similar positions of the 100 $\mu\text{g/L}$ contour lines for 1985 and 1992 suggest that the chlorobenzene plume has stabilized onsite. However, an additional well is necessary in the vicinity of the northwest corner of Lot F to determine if VOCs have migrated west of Lot F in this area of the site.

11.3 Deep Zone

Since all of the deep zone monitoring wells were installed by 1985, the benzene and chlorobenzene data from 1985 were compared to 1992 concentrations to determine whether the plume identified in 1985 has stabilized. Data from 1991 was plotted for well GM-31C since this well was last sampled during that year.

Benzene concentrations for 1985 and 1992 have been plotted in Figure 10 (Appendix B). A comparison of the benzene concentrations indicates a general improvement of water quality between 1985 and 1992. Specifically, a decrease in concentrations in downgradient wells GM-17C and GM-31C, and the continued absence of benzene in downgradient well GM-4B and side gradient well GM-10B.

Chlorobenzene concentrations for 1985 and 1992 have been plotted in Figure 11 (Appendix B). A comparison of the chlorobenzene results indicates that concentrations in downgradient wells GM-4C and GM-17C have increased between 1985 and 1992. However, concentrations have decreased at wells GM-10C and GM-31C.

Without additional downgradient monitoring wells in the deep zone, it is difficult to determine whether the benzene or chlorobenzene plumes have stabilized onsite.

12.0 GROUND-WATER QUALITY IN 1994

In September 1994, as part of the plant's ground-water monitoring program, ground-water samples were collected from 20 wells in the plant area, Lot F, and Village of Sauget property. The wells sampled and the list of analytical parameters are provided in Table 1 (Appendix I). The results from the September 1994 sampling round were added to the site ground-water database, which is provided in Appendix G. Based on the existing ground-water quality data, all samples were analyzed for Appendix IX VOCs and selected wells were also analyzed for Appendix IX semivolatile organic compounds (acid extractable and base neutral extractable compounds). In addition, 10 site-specific semivolatile organic compounds were added to the Appendix IX list of parameters, as shown in Table 1 (Appendix I).

12.1 Water-Table (Shallow) Zone

Ground-water quality data for the water-table (shallow) zone are provided in Appendix G. An evaluation of VOCs, acid extractable and base neutral extractable organic compounds that are present in the water-table zone in 1994 is provided below.

12.1.1 Volatile Organic Compounds

Similar to past sampling events, benzene and chlorobenzene are the primary constituents of concern and are present in upgradient well GM-12A at 3,200 µg/L, well GM-9A (2,210 µg/L), and well GM-17A (690,000 µg/L). VOCs were not detected in well GM-10A (northern portion of the site), nor in downgradient wells GM-4A and GM-5. The absence of any VOCs (specifically benzene and chlorobenzene) in well GM-5 is significant because this well is downgradient of the portion of the water-table aquifer that contains the highest concentrations of benzene and chlorobenzene.

Well GM-58A is located downgradient of the Route 3 drum site and VOCs were not detected in 1994. In addition, well GM-54A is located downgradient of well GM-58A and it too was absent of VOCs in 1994.

Based on the results presented above, it does not appear that VOCs are migrating offsite via the water-table zone.

12.1.2 Acid Compounds

Acid extractable compounds were monitored in well GM-5 (downgradient of the plant area) and wells GM-54A and GM-58A which are downgradient of the Route 3 drum site. No acid extractable compounds were detected in 1994. This is particularly important for the Route 3 drum site since phenolic compounds used to be key constituents in this area of the site.

Based on the results presented above, it does not appear that these compounds are migrating offsite via the water-table zone.

12.1.3 Base Neutral Compounds

Base neutral compounds were monitored in well GM-5 (downgradient of the plant area), and wells GM-54A and GM-58A (downgradient of the Route 3 drum site) in 1994. No base neutral compounds were detected in well GM-5. In well GM-58A (about 150 feet downgradient of the Route 3 drum site), 29 µg/L of 2- and 4-nitrochlorobenzene were detected. In well GM-54A (about 200 feet downgradient of well GM-58A) no base neutral compounds were found.

Based on the results presented above, it does not appear that these compounds are migrating offsite via the water-table zone.

12.2 Intermediate Zone

Ground-water quality data for the intermediate zone are provided in Appendix G. An evaluation of VOCs, acid extractable and base neutral extractable compounds that are present in the intermediate zone in 1994 is provided below.

12.2.1 Volatile Organic Compounds

VOCs, specifically benzene and chlorobenzene, are the compounds most frequently detected in the intermediate zone and in the highest concentrations. The monitoring program's results are provided in Appendix G (Table 1). VOCs (benzene only) were detected in upgradient well GM-12B at 9,400 µg/L. VOCs (benzene and chlorobenzene only) were detected in well GM-9B (3,840 µg/L) along the plant's southern boundary, and in well GM-10B (chlorobenzene only) at 2,300 µg/L at the plant's northern boundary. VOCs (benzene and chlorobenzene only) were detected in downgradient wells GM-4B and GM-17B at concentrations of 44,900 µg/L (average of duplicate results) and 1,200 µg/L, respectively. Farther downgradient, near the plant's downgradient property boundary, concentrations were significantly reduced in well GM-20B. In this well, chlorobenzene was detected at 450 µg/L and 1,1-dichloroethane was detected at 41 µg/L. In November 1992, only chlorobenzene was detected at 20 µg/L.

Based on the results of these data, it appears that the area of impacted ground water terminates near the western boundary of Lot F. Since well GM-20B is located on the property of the Village of Sauget primary treatment plant, it is not clear whether an off-site source has impacted ground water in this area.

Well GM-54B is located about 350 feet downgradient of the Route 3 drum site. Although 340 µg/L of chlorobenzene was detected in this well in 1994, chlorobenzene is not a compound that can be related to the drum site based on shallow water quality data. It is likely that the detection of chlorobenzene is the result of the relatively ubiquitous presence of this compound in the intermediate zone and not from the Route 3 drum site which is covered with a RCRA cap. In addition, historical water-level data for well clusters in this area indicate that a downward head gradient is not present in this area of the site. Without a downward driving force, there is no mechanism for chemicals to migrate downward into the intermediate zone.

Based on the data presented above, the terminus of the VOC plume appears to be near the western boundary of Lot F.

12.2.2 Acid Compounds

In 1994, acid extractable compounds were monitored in wells GM-4B, GM-17B, and GM-20B which are downgradient of the plant area and in well GM-54B which is downgradient of the Route 3 drum site. Acid extractable compounds were not detected in well GM-17B; however, 84 µg/L of phenol was detected in well GM-4B near Route 3. Monitoring well GM-20B is located farther downgradient and no acid compounds were detected.

Well GM-54B is located downgradient of the Route 3 drum site and no acid compounds were detected.

Based on the data presented above, it does not appear that acid compounds are migrating offsite via the intermediate zone.

12.2.3 Base Neutral Compounds

In 1994, base neutral compounds were monitored in wells GM-4B, GM-17B, and GM-20B which are downgradient of the plant area and in well GM-54B which is downgradient of the Route 3 drum site.

Several base neutral compounds were detected in wells GM-4B and GM-17B located along Route 3. In well GM-4B bis(2-ethylhexyl)phthalate was detected in a sample and its duplicate at concentrations of 150 and 240 µg/L; however, these results are suspect because this compound is often a laboratory artifact and it was not detected during past sampling events. No other base neutral compounds were detected in the initial sample collected from GM-4B; however, several compounds were detected in the duplicate sample collected which include: aniline (110J µg/L), 2- and 3-chloroaniline (59 µg/L), and 4-chloroaniline (130 µg/L). Several base neutral compounds were also detected in well GM-17B which include: 1,4-dichlorobenzene (170 µg/L), 2,4- and 2,4-dinitrochlorobenzene (10 µg/L), 2- and 3 chloroaniline (1,400 µg/L), and 4-chloroaniline (370 µg/L). Further downgradient, at well GM-20B, fewer constituents at lower concentrations were detected and were reported as follows: 1,4-dichlorobenzene (83 µg/L) and

2-chloroaniline (140 µg/L). As stated earlier, well GM-20 is located in the vicinity of the Village of Sauget's primary treatment plant and Village operations may have impacted the water quality in this well.

Well GM-54B is located downgradient of the Route 3 drum site and only bis(2-ethylhexyl) phthalate was detected (50 µg/L). As discussed earlier, this compound is often a laboratory artifact.

Based on the results presented above, site-related base neutral compounds may be migrating offsite through the area upgradient (east) of well GM-20B.

12.3 Deep Zone

Ground-water quality for the deep zone is provided in Appendix G. An evaluation of the VOCs, acid compounds and base neutral compounds that are present in the deep zone in 1994 is provided below.

12.3.1 Volatile Organic Compounds

VOCs, specifically benzene and chlorobenzene, are the compounds most frequently detected in the deep zone and in the highest concentrations. Chlorobenzene was detected at 15 µg/L in upgradient well GM-12C, no other VOCs were detected. VOCs (benzene and chlorobenzene only) were detected in well GM-9C (350 µg/L) along the plant's southern boundary, and in well GM-10C (chlorobenzene only) at 120 µg/L at the plant's northern boundary. These concentrations are significantly lower than those found in the intermediate zone. In downgradient monitoring wells GM-4C, benzene was detected at 32,000 µg/L and chlorobenzene was not detected. Chlorobenzene usually ranges from 10,000 to 20,000 µg/L with little or no benzene being reported. It appears that the results were reversed; however, the laboratory is confident that the data are correct. In well GM-17C benzene and chlorobenzene were detected at concentrations of 4,200 and 27,000 µg/L, respectively. The higher results in GM-4C and GM-17C are not consistent with ground-water flow because a downward gradient does not exist

between the intermediate and deep zones. However, as discussed earlier in this report, past ground-water withdrawals may be responsible for drawing these compounds down into the deep zone.

Based on the results presented above, benzene and chlorobenzene may be migrating offsite through the deep zone.

12.3.2 Acid Compounds

In 1994, acid extractable compounds were monitored in wells GM-4C and GM-17C which are both downgradient of the plant area; no acid compounds were detected.

Based on the results presented above, acid compounds are not migrating offsite via the deep zone.

12.3.3 Base Neutral Compounds

In 1994, base neutral compounds were monitored in wells GM-4C and GM-17C which are both downgradient of the plant area; and several base neutral compounds were detected. In well GM-4C, 53 µg/L of bis(2-ethylhexyl)phthalate was reported; however, its presence may be a laboratory artifact. In addition, several other compounds were detected which include: aniline (70 µg/L), 1,4-dichlorobenzene (26 µg/L), 2- and 3-chloroaniline (50 µg/L), and 4-chloroaniline (64 µg/L). A similar suite of compounds was detected in well GM-17C at the following concentrations: 1,4-dichlorobenzene (520 µg/L), 2- and 3-chloroaniline (380 µg/L), and 4-chloroaniline (170 µg/L). The levels of constituents in the deep zone at these two locations are generally less than their respective concentrations in the intermediate zone.

Based on the information presented above, it is not clear whether base neutral compounds are migrating offsite via the deep zone.

13.0 SUMMARY OF FINDINGS

An evaluation of the ground-water quality data that has been developed during the plant's ground-water monitoring program is provided below.

1. In the water-table zone, ground water has been impacted by VOCs (specifically benzene and chlorobenzene), and to a lesser extent by acid and base neutral p 18Xbase neutral c (semivolatile compounds). Based on the results of the ground-water monitoring program, the plume of impacted ground water has stabilized onsite. Although ground water has been impacted to varying degrees downgradient of the plant area and at the Route 3 drum site, the constituents in ground water have not migrated very far in this zone.
2. In the intermediate zone, ground water has been impacted by VOCs (benzene and chlorobenzene) and base neutral compounds, and to a much lesser extent, acid compounds. The results of the ground-water monitoring program indicate that the plume has stabilized, and the extent of the plume of impacted ground water appears to terminate near the western boundary of Lot F. In the vicinity of the Route 3 drum site, low levels of constituents have been detected in downgradient monitoring wells, however, the drum site was probably not the source.
3. In the deep zone, ground water has been impacted by VOCs (benzene and chlorobenzene) and base neutral compounds, and to a much lesser extent, acid compounds. Based on the results of the ground-water monitoring program, additional data along the plant's perimeter is needed to determine whether the plume of impacted ground water has migrated offsite.
4. Based on the 1992 and 1994 analytical results that targeted Appendix IX parameters (as compared to past analyses of priority pollutant compounds), no additional compounds were found that had not been detected during past sampling events.

14.0 RECOMMENDATIONS

Based on Roux Associates' analysis of the ground-water quality data collected at the plant since 1984, we recommend that several additional wells be installed to complete the monitoring well network. Our recommendations are provided below.

1. Due to the uncertainty as to whether VOCs (specifically, benzene and chlorobenzene) and several base neutral compounds are migrating offsite via the intermediate zone, we recommend the monitoring well network be expanded (see Figure 1). The expanded network would include an additional intermediate well west of GM-4B near the western boundary of Lot F, and a second well west of well GM-6B, also near the western boundary of Lot F. At the present time, we believe the location of well GM-20B on Village of Sauget property is satisfactorily located to monitor ground water migrating westward from the center of the plant.
2. Due to the uncertainty as to whether VOCs (specifically, benzene and chlorobenzene) and several base neutral compounds are migrating offsite via the deep zone, we recommend the monitoring well network to be expanded (see Figure 1). The expanded network would include three new wells as follows: a deep well west of GM-4C near the western boundary of Lot F, a deep well west of GM-17C near the western boundary of Lot F, and a deep well west of GM-6C near the western boundary of Lot F. Based on these three additional wells, it should be clear as to whether any constituents are migrating offsite.
3. We propose that the intermediate and deep wells be constructed of similar materials as in the past (stainless steel screens and either black steel or PVC riser). In addition, each new intermediate and deep well should be installed at similar depths (or elevations) of existing wells with regard to the respective zone for which the wells will be monitoring.

15.0 REFERENCES

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